Design and Development of Miniature Direct Methanol Fuel Cell Power Sources for Cellular Phone Applications

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Introduction

The demand for compact power sources with high energy density has been steadily increasing. Increased cellular phone usage has continued to press for longer talk times and fewer interruptions for battery recharging. Thus, the high energy density of 150 Wh/kg and the low recharge time offered by advanced rechargeable lithium ion batteries continue to be limitations to the cellular phone users. Direct methanol fuel cells are potentially capable of overcoming these limitations and offering energy densities as high as 1500 Wh/ kg. By replenishing the fuel, talk times on cellular phones can be extended as long as needed, eliminating the need for electrical recharging. The interest in miniature fuel cells has been quite recent [1-4]. This is also a consequence of advances in direct methanol fuel cells [5-11]. The direct methanol fuel cell starts up at room temperature, is truly load-following, does not require pre-processing of the fuel to hydrogen, and allows for easy liquid fuel storage. These characteristics make the direct methanol fuel cell an excellent candidate for a miniature power source. The following summarizes recent efforts at the Jet Propulsion Laboratory on the development of miniature direct methanol power sources for cellular phone use.

Power requirements and configuration of fuel cell power source

We have measured the power requirements of a few currently available cellular phones and concluded that they vary considerably. The power demand in the standby mode is in the range of 100- 150 mW. During operation (dialing or receiving calls) the power demand varies considerably with the type of cellular phone and can range from 800 -1800 mW.

A direct methanol fuel cell power source for cellular phone purposes is configured preferably to operate on a pure methanol feed that is appropriately diluted when delivered to the surface of the electrode. The power source will rely on ambient pressure air with natural convection much like small metal-air batteries. The product water and carbon dioxide will be contained within the power source package. A combined fuel-supply/product-capture cartridge could then be replaced to extend capacity. It is preferable that the fuel cell power source be part of the cellular phone and take on the form factor of current day cellular phone batteries. Our estimates based on current technology suggest that a 1 W fuel cell power source occupying 50 ml and weighing 50 grams would be able to offer a talk time of about 10 hours at a fuel cell efficiency of about 20%. The 10-hour talk time requires just 10 ml of pure methanol. If this can be realized in practice, it would already be a three-fold improvement over the currently available rechargeable batteries without the need to recharge electrically. The design issues relating such a development will now be discussed.

Operation on air with natural convection

About two years ago we developed membrane electrode assemblies with improved cathodes that are capable of operating at ambient pressure and very low flow rates of air. The performance of such a cell under natural convection air and room temperature is shown in Fig.1. These performance levels satisfy the minimum requirements for a cellular phone power source. This type of membrane electrode assemblies was therefore considered with various stack designs.

Stack design

In conventional stack designs bipolar plates are responsible for over 70% of the weight of the fuel cell stack. In addition, the bipolar stack design is only advantageous to reduce resistance losses at high power densities. Recent reports from Samsung Corp. [4] suggest the possibility of using extremely thin lightweight biplates to overcome this problem. We have chosen not to use the conventional bipolar stack design and have developed a "flat-pack" design with no bipolar plates.

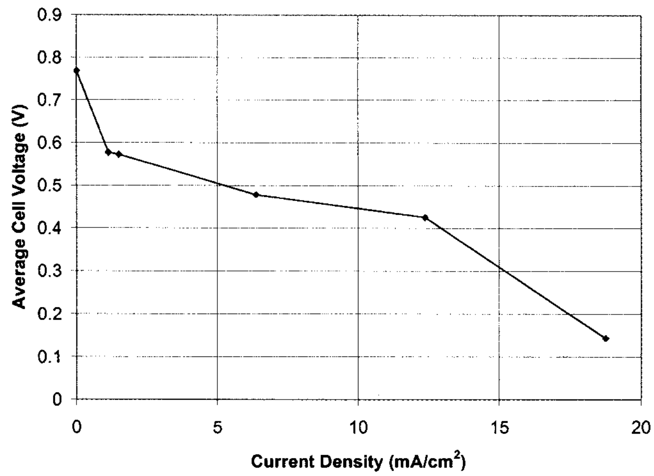

Figure 1. Performance of direct methanol fuel cells under natural convection air at 25 C, 0.5 M methanol

In this design, cells are interconnected in series on the same membrane plane with through the membrane electrical interconnects. This is similar to the "monopolar" or "strip-cell" design evaluated for direct hydrogen fuel cells [12]. The "flat-pack" design is shown in figure 2. Two flat-packs can be deployed in a back-to-back configuration with a common methanol feed to form a "twin pack" as shown in Figure 2.

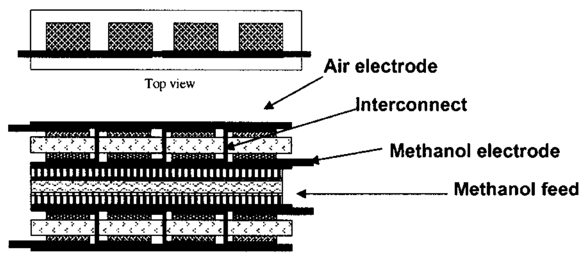

Figure 2. Schematic of interconnected cells in a "flat-pack" direct methanol fuel cell

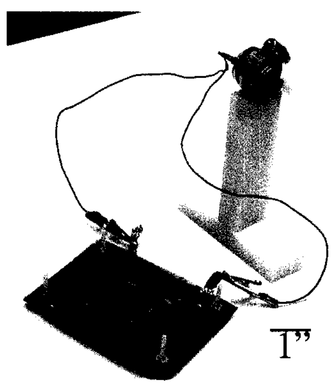

Figure 3. Six-cell direct methanol fuel cell "flat-pack" in operation

Figure 3 shows a "flat-pack" with six electrodes in series. The electrodes on one side of the "flat-pack" are supplied with a methanol solution held in a thin porous matrix while the other side of the flat-pack is exposed to air. The single layer pack shown in Figure 3 is capable of producing 150 mW continuously. About three twin packs can be used in series to power a cellular phone. The flat-pack design results in a higher electrical resistance as compared to that of a bipolar stack with the same active electrode area and number of cells. Thus the choice of materials, geometric configuration, and interconnect design of a "flat-pack" must focus on minimizing the internal electrical resistance and preserving a uniform current distribution. Three generations of flat-pack direct methanol fuel cells have been fabricated and evaluated. The results shown in Table 1 suggest that internal resistance of the flat-pack is largely governed by the resistance of the interconnects.

Table 1. Characteristics of various flat-pack methanol fuel cells

Generation ID of "Flat-cell" Pack	Current Path length, Arbitrary units	Interconnect Area, cm^2	Electrical Resistance at 1 kHz, Ohm
Generation 1	30	0.15	9.6
Generation 2	30	0.35	6
Generation 3	1	1.1	3.2

Figure 4 shows the progressive improvements in the electrical performance of the flat-pack performance resulting from the reduction of internal resistance.

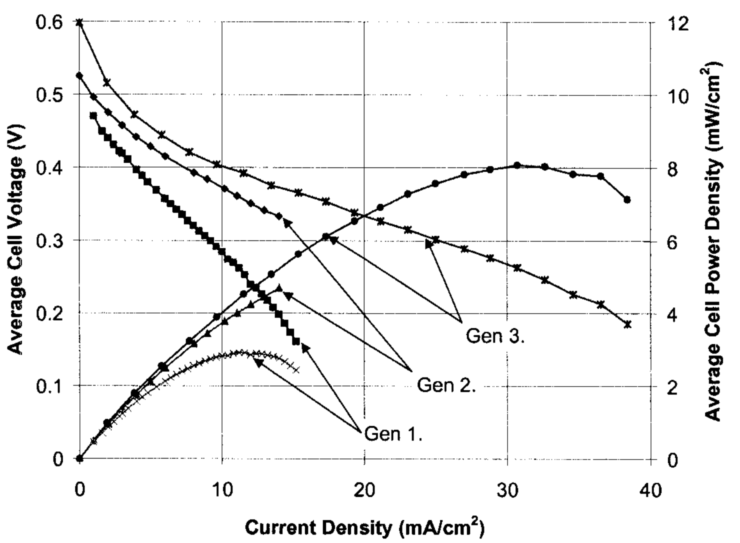

Figure 4. Cell voltage and power density of three generations of flat-cell DMFC packs at 20-25°C, 1 M methanol, ambient air, natural convection.

Summary

The above findings show that the "flat-pack" direct methanol fuel cell approach is attractive for the miniaturization of the fuel cell system. Interconnect resistance losses can be minimized further by the use of highly conducting materials. Future versions of the flat-pack fuel cell will aim at including electrode modifications, micro-channel structures and active mass movement for removal and circulation of consumables and products.

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